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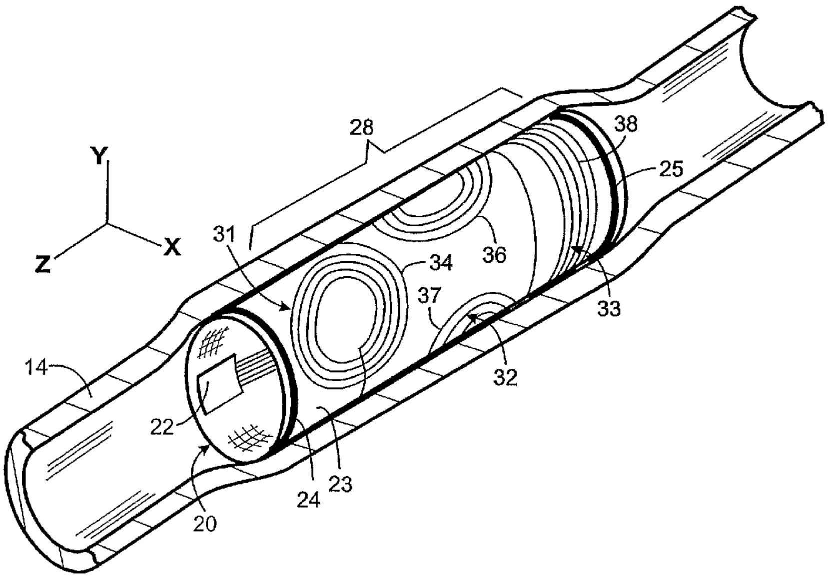
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OMNIDIRECTIONAL RADIO FREQUENCY SIGNAL RECEIVING ANTENNA FOR AN IMPLANTABLE MEDICAL DEVICE



(57) Abstract: A radio frequency antenna assembly is provided for a medical device such as one capable of being implanted into a patient. The antenna assembly includes a plurality of antennas, each oriented to receive a radio frequency signal propagating along a different direction. This facilitates reception of the radio frequency signal regardless of the orientation of its propagation direction to the medical device. In other cases, the radio frequency signal has a plurality of components, each propagating along a different direction, and each antenna of the assembly receives a different one of those components. The individual electrical signals produced in each antenna are additively combined into a single signal having greater strength than each of the individual electrical signals.

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OMNIDIRECTIONAL RADIO FREQUENCY SIGNAL RECEIVING ANTENNA FOR AN IMPLANTABLE MEDICAL DEVICE

Cross-Reference to Related Applications

Not Applicable

Statement Regarding Federally Sponsored Research or Development

Not Applicable

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to medical devices for implanting into an animal, such as cardiac stimulation devices, and more particularly to such medical devices that receive radio frequency signals via an antenna.

2. Description of the Related Art

[0002] A remedy for people with slowed or disrupted natural heart beats is to implant a cardiac pacing device which is a small electronic apparatus that stimulates the heart to beat at regular intervals. That device consists of a pulse generator, implanted in the patient's chest, which produces electrical pulses that stimulate heart contractions. Electrical wires extend from the pulse generator to several electrodes placed nearby specific muscles of the heart, which when electrically stimulated produce contraction of the adjacent heart chambers.

[0003] It is quite common that the wires extend through arteries or veins which enter the heart so that the electrodes can be placed in the muscle of the heart chamber requiring stimulation. The wires typically extend for some distance in the arteries or veins and may pass through one or two heart valves. In other patients, patch electrodes are placed on the exterior heart surface with wires extending through tissue to the pacing device. With either type of wire placement, it is important that the electrodes be attached at proper positions on the heart to stimulate the muscles and produce contractions. Thus, it is desirable to properly locate the electrodes for maximum heart stimulation with minimal adverse impact to other physiological functions, such as blood circulation.

[0004] More recently wireless pacing devices have been proposed, such as the one described in U.S. Patent No. 6,445,953. With this type of device, a radio frequency (RF) signal is transmitted from a conventional pacing circuit to stimulator devices placed on the heart at locations where stimulation is to occur. For example, the stimulator device can be implanted in a blood vessel of the heart. The radio frequency signal activates the device which applies an electrical pulse to the heart tissue. Electrical power for stimulating the heart is derived from the energy of the radio frequency signal.

[0005] One of the difficulties in such a wireless system is ensuring that the radio frequency signal and a maximum amount of the RF energy is received by the stimulator device. In the case of that prior patented device, the antenna was a coil wrapped around a cylindrical structure that was embedded against the wall of a vein or artery. That type of antenna received the greatest amount of energy from an electromagnetic field oriented in a direction through the turns of the coil. However, since the antenna can be implanted in different orientations in the patient's body depending on the location of the vein or artery and the orientation of the transmitter antenna similarly varies, it is difficult to ensure that the electromagnetic field from the RF signal will be properly aligned with the antenna of the implanted device. Because the location at which the medical device is implanted is based primarily on cardiac stimulation criteria, it is not always possible to optimally orient its antenna for maximum energy reception.

[0006] A proposed transmitter, for sending signals to the implanted medical device, employs an omnidirectional antenna which emits B fields that propagate along three orthogonal axes. Thus one of those B fields or a vector sum of two or all of them will be aligned with the antenna coil of the implanted medical device. Although this solves the problem of misalignment of the transmitter and receiver antennas, the RF energy from all the B fields is not received by the implanted device. Since that device is powered by the RF energy, it is desirable to receive as much of the transmitted energy as possible. That desire is especially acute when the medical device is an implanted defibrillator as such apparatus requires a relatively large amount of power to defibrillate a heart.

Summary of the Invention

[0007] An antenna assembly is provided by which a medical device, such as one implanted in a patient, receives a radio frequency signal. The assembly has a first antenna oriented on the medical device to receive a component of the radio frequency signal that is oriented or propagates in a first direction. A second antenna is oriented on the medical device to receive a component of the radio frequency signal that is oriented or propagates in a second direction that is transverse to the first direction.

[0008] In one version of the antenna assembly the first and second antennas are oriented along separate orthogonal axes. Preferably, each of the first and second antennas comprises two conductive coils that are electrically connected together and spaced apart along the respective axis. The preferred embodiment of the antenna assembly further includes a third antenna oriented along a third axis that is orthogonal to both the first and second axes.

[0009] Another aspect of the present antenna assembly provides a circuit that is operably connected to combine electrical signals produced in all the antennas.

[0010] The present antenna assembly is particularly adapted for use with an implanted medical device that has a cylindrical body. Here, a first antenna is oriented on the cylindrical body to receive the radio frequency signal and a second antenna is oriented on the cylindrical body at a location that is spaced 90° circumferentially from the first antenna. Each of the first and second antennas may comprise two coils located on opposite sides of the body and interconnected so that electrical signal produced in the two coils additively combine. In this medical device, a third antenna may be wound circumferentially around the body.

[0011] The various versions of the present antenna assembly provide multiple antennas each for receiving the radio frequency signal that has a component oriented in a given direction. This enhances reception of the radio frequency signal regardless of the orientation of the medical device to the direction of that component. In other cases, the radio frequency signal has a plurality of components, each oriented in a different direction and each antenna of the assembly receives a different one of those components. The individual electrical signals produced in each antenna are additively combined into a single signal having greater strength than each of the individual components.

Brief Description of the Drawings

[0012] FIGURE 1 depicts a cardiac pacing apparatus implanted in a patient;

[0013] FIGURE 2 is an isometric, cut-away view of a blood vessel with a cardiac stimulation device implanted therein;

[0014] FIGURE 3 is a schematic block diagram of an electrical circuit on the stimulation device; and

[0015] FIGURE 4 depicts one of the antennas of the stimulation device.

Detailed Description of the Invention

[0016] With initial reference to Figure 1, an apparatus 10 for applying electrical stimulation to a heart 11 comprises a pacing device 12 and one or more stimulators 20 and 21 located in arteries or veins 14 through which blood flows within the heart muscles. As will be described in greater detail, the pacing device 12 emits a radio frequency signal 16 which produces an electric voltage in the implanted vascular stimulators, thereby stimulating the heart muscle to contract. The radio frequency signal 16 preferably comprises a set of electromagnetic waves that propagate along three orthogonal axes, however that signal alternatively may comprise a single electromagnetic wave or other pluralities of waves. For example the transmitted signal may be circularly polarized with multiple components having phase differences of 90 degrees. Although the present invention is being described in the context of an apparatus for pacing the heart, the novel antenna system can be used with defibrillators and other implantable medical devices.

[0017] Referring to Figure 2, a stimulator 20 is placed in the artery or vein 14 of the heart 11. The body 23 of the stimulator 20 has a design similar to well-known vascular stents and is in the form of a tube that initially is collapsed to a relatively small diameter enabling it to pass freely through arteries or veins of a patient. The procedure for implanting the stimulator 20 is similar to that used for vascular stents. For example, the balloon at the end of a standard catheter is inserted into the annulus of the stimulator 20 in the collapsed, or reduced diameter, configuration. That assembly is inserted through an incision in a vein or artery near the skin of a patient and threaded through the vascular system to the appropriate location in the heart. Specifically, the stimulator 20 ultimately is positioned in a cardiac artery or vein 14 adjacent to a section of the heart muscle where stimulation should be applied. The balloon of the catheter then is inflated to expand the vascular stimulator 20 which, as seen in Figure 2, embeds the stimulator against the wall of the blood vessel. The balloon is deflated, the catheter is removed from the patient, and the incision is closed. Thereafter, the tubular configuration of the stimulator allows blood to flow relatively unimpeded through the artery or vein.

[0018] With reference to Figures 2 and 3, a signal receiving circuit 22 is mounted on the body 23 of the vascular stimulator 20. The signal receiving circuit 22 includes an antenna array 28, a passive RF signal combiner 27, a radio frequency signal detector 26, and first and second electrodes 24 and 25. The antenna array 28 preferably comprises three antennas 31, 32 and 33 connected by a signal combiner 27 to inputs of the radio frequency signal detector 26 that is tuned to the frequency (e.g. 27 MHz.) of the RF signal 16 emitted by the pacing device 12. However, the detector does not necessarily have to be a tuned circuit. Upon receiving the radio frequency signal 16, the detector 26 converts the energy of that signal into a differential voltage pulse that is applied across the first and second electrodes 24 and 25. Those electrodes form an electric circuit path with the patient's heart tissue, thereby stimulating that tissue. Thus, each time the pacing device 12 emits a radio frequency signal 16, a pulse of electrical voltage is produced in the vicinity of the stimulator 20 to stimulate the adjacent heart muscle.

[0019] The three separate antennas 31, 32 and 33 of the antenna array 28 are oriented on the body 23 to receive radio frequency electromagnetic waves that propagate along three orthogonal axes designated X, Y and Z, respectively. The first antenna 31 includes first and second coils 34 and 35 mounted on opposite lateral sides of the exterior surface of the body 23 (only one of those coils 34 is visible in Figure 2, but see Figure 4). The first antenna 31 receives electromagnetic waves, or components of such waves, that propagate in the X axis. The second antenna 32 is formed by third and fourth coils 36 and 37 mounted on the top and bottom of the exterior surface of the body 23 and receives electromagnetic waves, or components of such waves, that propagate in the Y axis. It should be understood that the directional references herein to lateral sides, top, and bottom are for understanding the physical relationship between the first and second antennas 31 and 32 and relates only to the orientation of the stimulator body 23 in Figure 2, which orientation may be rotated in a particular installation of the stimulator in a patient. The third antenna 33 is a single fifth coil 38 that is wound circumferentially around the exterior surface of the body 23 to receive electromagnetic waves, or components of such waves, that propagate in the Z axis. The ends of the fifth coil 38 are connected to the RF signal combiner 27 which is a passive network that combines the signals from the three antennas 31-33 into a single signal that is fed to the detector 26.

[0020] The interconnection of the first and second coils 34 and 35 of the first antenna 31 is depicted in Figure 4. It should be understood that the third and fourth coils 36 and 37 of the second antenna 32 have the same construction as coils first and second 34 and 35, respectively, with the only distinction being rotation 90° around the circumference of the body 23. The first coil 34 has a first end 40 connected by a conductor 42 to the signal combiner 27 of the signal receiving circuit 22. The first coil 34 is wound counterclockwise in an increasing radius spiral until reaching a second end 44. The number of turns of the spiral is chosen for optimum reception of the particular frequency of the RF signal from the pacing device 12. The second end 44 of the first coil 34 is connected by a linking conductor 46 to a first end 48 of the second coil 35.

[0021] The second coil 35 is centered diametrically opposite the center of the first coil 34 along axis 47 and is wound from its first end 48 in a counterclockwise decreasing radius spiral until reaching a second end 50. The second coil 35 preferably has the same number of turns as the first coil 34. The second end 50 of the second coil 35 is connected by another conductor 46 to the signal combiner 27. It should be understood that the spirals of the first and second coils 34 and 35 may be wound in the opposite direction that those shown in Figure 4. However, electric current induced in the first antenna by the RF signal from the pacing device 12 must flow in the same direction, clockwise or counterclockwise in both coils. In other words, the two coils 34 and 35 are wound so that the electric voltage induced in each one combine in an additive manner to produce a resultant voltage that is greater than the voltage induced in either coil alone.

[0022] The foregoing description was primarily directed to a preferred embodiment of the invention. Although some attention was given to various alternatives within the scope of the invention, it is anticipated that one skilled in the art will likely realize additional alternatives that are now apparent from disclosure of embodiments of the invention. Accordingly, the scope of the invention should be determined from the following claims and not limited by the above disclosure.

CLAIMS

What is claimed is:

1. An antenna assembly by which a medical device receives a radio frequency signal that has a B field, said antenna assembly comprising:

a first antenna oriented at the medical device to receive a B field that is oriented in a first direction;

an electromagnetic wave propagating along a first axis; and

a second antenna oriented at the medical device to receive to receive a B field that is oriented in a second direction that is transverse to the first direction.

2. The antenna assembly as recited in claim 1 wherein the second direction is orthogonal to the first direction .

3. The antenna assembly as recited in claim 1 wherein the first antenna and the second antenna each comprises a conductive coil wherein the conductive coil of the first antenna is orthogonal to the conductive coil of the second antenna.

4. The antenna assembly as recited in claim 1 further comprising a third antenna oriented at the medical device to receive a B field that is oriented in a third direction that is transverse to the first direction and the second direction.

5. The antenna assembly as recited in claim 4 wherein the first antenna, the second antenna, and the third antenna each comprises a conductive coil wherein the conductive coil of each antenna is orthogonal to the conductive coil of the other antennas.

6. The antenna assembly as recited in claim 1 wherein:

the first antenna comprises a first conductive coil connected to and spaced from a second conductive coil along a first axis; and

the second antenna comprises a third conductive coil connected to and spaced from a fourth conductive coil along a second axis.

7. The antenna assembly as recited in claim 6 further comprising a third antenna that has a fifth conductive coil wound about a third axis that is transverse to the first axis and the second axis.

8. The antenna assembly as recited in claim 1 further comprising a circuit connected to the first antenna and the second antenna and combining electrical signals produced in those antennas.

9. An antenna assembly by which a medical device that is implanted in a patient receives a radio frequency signal, wherein the radio frequency signal has at least a first B field, a second B field and a third B field each oriented in a different direction , said antenna assembly comprising:

a first antenna oriented at the medical device so as to receive the first B field;

a second antenna oriented at the medical device so as to receive the second B field; and

a third antenna oriented at the medical device so as to receive the third B field.

10. The antenna assembly as recited in claim 9 wherein the first antenna, the second antenna, and the third antenna each comprises a conductive coil wherein the conductive coil of each antenna is orthogonal to the conductive coil of the other antennas.

11. The antenna assembly as recited in claim 10 wherein the medical device has a cylindrical body and the conductive coil of the first antenna is mounted on the body, the conductive coil of the second antenna is mounted on the body and spaced 90° circumferentially from the conductive coil of the first antenna, and the conductive coil of the third antenna is wound circumferentially around the body.

12. The antenna assembly as recited in claim 9 wherein:

the first antenna comprises a first conductive coil and a second conductive coil that is connected to and spaced from the first conductive coil along a first axis; and

the second antenna comprises a third conductive coil and a fourth conductive coil that is connected to and spaced from the third conductive coil along a second axis that is transverse to the first axis.

13. The antenna assembly as recited in claim 12 wherein the first axis is substantially orthogonal to the second axis.

14. The antenna assembly as recited in claim 12 wherein the third antenna comprises a fifth conductive coil wound about along a third axis that is transverse to the first axis and the second axis.

15. The antenna assembly as recited in claim 9 further comprising a circuit connected to the first antenna, the second antenna, and the third antenna and combining electrical signals produced in those antennas.

16. An antenna assembly by which a medical device implanted in a patient receives a radio frequency signal, wherein the medical device has a cylindrical body, said antenna assembly comprising:

a first antenna oriented on the cylindrical body to receive the radio frequency signal; and

a second antenna oriented on the cylindrical body and spaced 90° circumferentially from the first antenna.

17. The antenna assembly as recited in claim 16 wherein the first antenna and the second antenna each comprises a conductive coil wherein the conductive coil of the first antenna is orthogonal to the conductive coil of the second antenna.

18. The antenna assembly as recited in claim 16 further comprising a third antenna having another conductive coil wound circumferentially around the body.

19. The antenna assembly as recited in claim 16 wherein:

the first antenna comprises a first conductive coil and a second conductive coil that is connected to and spaced from the first conductive coil along a first direction; and

the second antenna comprises a third conductive coil and a fourth conductive coil that is connected to and spaced from the third conductive coil along a second direction that is orthogonal to the first direction.

20. The antenna assembly as recited in claim 16 further comprising a third antenna having a fifth conductive coil wound circumferentially around the body.

AMENDED CLAIMS

[received by the International Bureau on 9th August 2006 (09.08.06)]

What is claimed is:

1. An antenna assembly by which a medical device receives a radio frequency signal that has a B field, said antenna assembly comprising:

a first antenna to receive a B field that is oriented in a first direction, wherein the first antenna includes a first conductive coil and a second conductive coil connected in series and spaced apart on opposite sides of a body of the medical device along a first axis; and

a second antenna to receive to receive a B field that is oriented in a second direction transverse to the first direction, wherein the second antenna includes a third conductive coil and a fourth conductive coil connected in series and spaced apart on opposite sides of the body of the medical device along a second axis.

2. The antenna assembly as recited in claim 1 wherein the second direction is orthogonal to the first direction.

3. The antenna assembly as recited in claim 1 wherein the second axis is substantially orthogonal to the first axis.

4. The antenna assembly as recited in claim 1 further comprising a third antenna oriented at the medical device to receive a B field that is oriented in a third direction that is transverse to the first direction and the second direction.

5. The antenna assembly as recited in claim 1 further comprising a third antenna that has a fifth conductive coil wound about a third axis that is transverse to the first axis and the second axis.

6. The antenna assembly as recited in claim 1 wherein the third antenna comprises a fifth coil wound about a third axis that is substantially orthogonal to the first axis and to the second axis.

7. The antenna assembly as recited in claim 1 further comprising a circuit connected to the first antenna and the second antenna and combining electrical signals produced in those antennas.

8. The antenna assembly as recited in claim 1 wherein the first coil is wound in an increasing radius clockwise spiral from a first end until reaching a second end; and the second coil has a third end connected to the second end and is wound in a decreasing radius counterclockwise spiral until reaching a fourth end.

9. The antenna assembly as recited in claim 1 wherein the third coil is wound in an increasing radius clockwise spiral from a first end until reaching a second end; and the fourth coil has a third end connected to the second end and is wound in a decreasing radius counterclockwise spiral until reaching a fourth end.

10. An antenna assembly by which a medical device that is implanted in a patient receives a radio frequency signal, wherein the radio frequency signal has at least a first B field, a second B field and a third B field each oriented in a different direction, said antenna assembly comprising:

a first antenna oriented at the medical device so as to receive the first B field, wherein the first antenna includes a first conductive coil and a second conductive coil connected in series and spaced apart on opposite sides of the medical device;

a second antenna oriented at the medical device so as to receive the second B field, wherein the second antenna includes a third conductive coil and a fourth conductive coil connected in series and spaced apart on opposite sides of the medical device; and

a third antenna having fifth conductive coil a oriented at the medical device so as to receive the third B field, wherein the third antenna includes.

11. The antenna assembly as recited in claim 10 wherein the first conductive coil and a second conductive coil are wound around a first axis, the third conductive coil and a fourth conductive coil are wound around a second axis, and the fifth coil is wound around a third axis.

12. The antenna assembly as recited in claim 11 wherein the first axis, second axis, and third axis are transverse to each other.

13. The antenna assembly as recited in claim 11 wherein the first axis, second axis, and third axis are substantially orthogonal to each other.

14. The antenna assembly as recited in claim 10 wherein the medical device has a cylindrical body and the first and second conductive coils are mounted on the body, the third and fourth conductive coils are mounted on the body and spaced 90° circumferentially from the first and second coils, and the fifth conductive coil is wound circumferentially around the body.

15. The antenna assembly as recited in claim 10 further comprising a circuit connected to the first antenna, the second antenna, and the third antenna and combining electrical signals produced in those antennas.

16. The antenna assembly as recited in claim 10 wherein:

the first coil is wound in an increasing radius clockwise spiral from a first end until reaching a second end, and the second coil has a third end connected to the second end and is wound in a decreasing radius counterclockwise spiral until reaching a fourth end; and

the third coil is wound in an increasing radius clockwise spiral from a first distal end until reaching a first remote end, and the fourth coil has a second distal end connected to the first remote end and is wound in a decreasing radius counterclockwise spiral.

17. An antenna assembly by which a medical device implanted in a patient receives a radio frequency signal, wherein the medical device has a cylindrical body, said antenna assembly comprising:

a first antenna oriented on the cylindrical body to receive the radio frequency signal, and comprising a first conductive coil and a second conductive coil connected in series and mounted on opposite sides of the cylindrical body; and

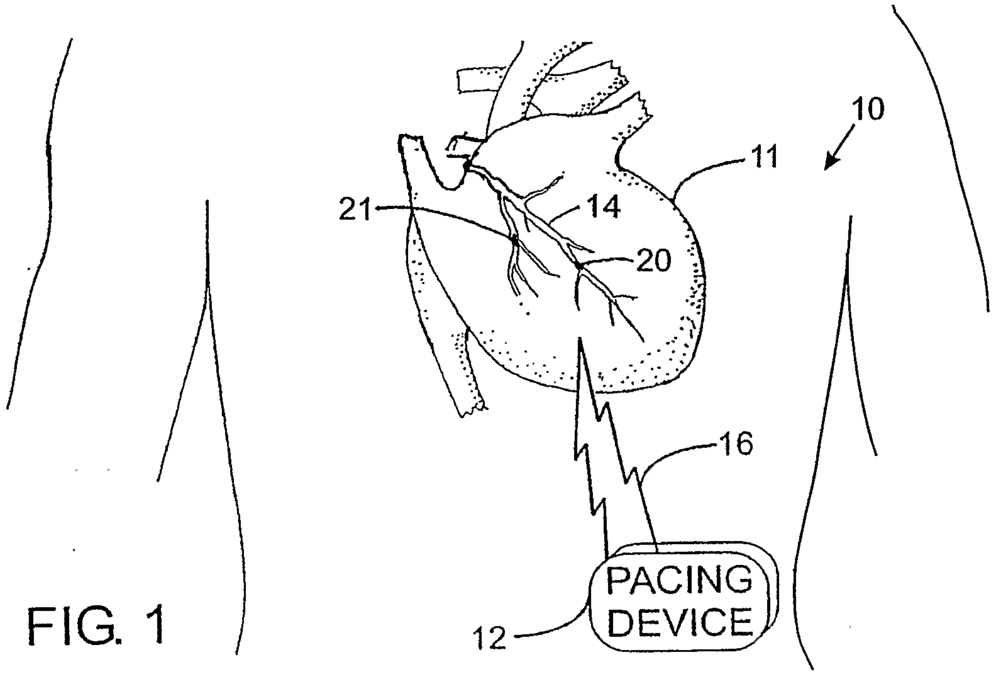
a second antenna spaced 90° circumferentially from the first antenna, and comprising a third conductive coil and a fourth conductive coil connected in series and mounted opposite sides of the cylindrical body.

18. The antenna assembly as recited in claim 17 further comprising a third antenna having a fifth conductive coil wound circumferentially around the body.

19. The antenna assembly as recited in claim 17 wherein:

the first coil is wound in an increasing radius clockwise spiral from a first end until reaching a second end, and the second coil has a third end connected to the second end and is wound in a decreasing radius counterclockwise spiral until reaching a fourth end; and

the third coil is wound in an increasing radius clockwise spiral from a first distal end until reaching a first remote end, and the fourth coil has a second distal end connected to the first remote end and is wound in a decreasing radius counterclockwise spiral.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PACING DEVICE
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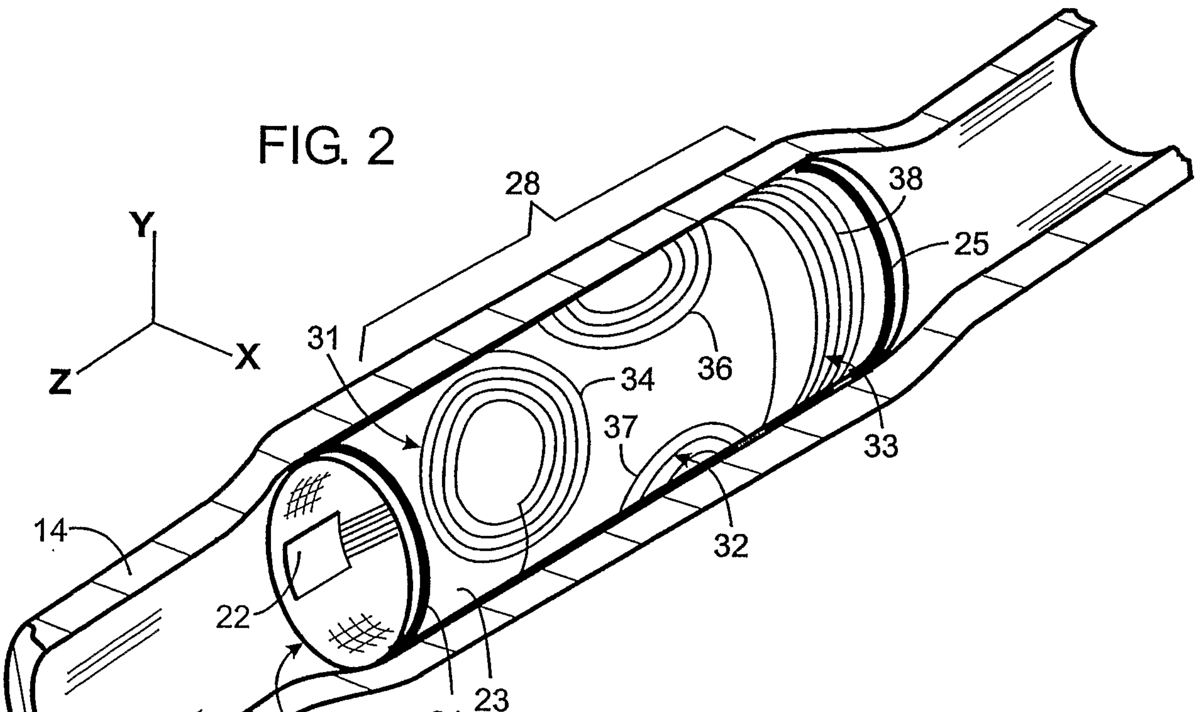
FIG. 1

FIG. 2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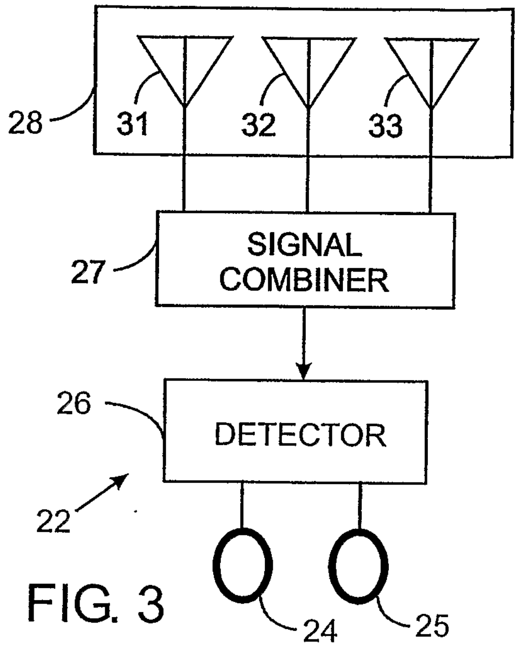
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FIG. 3

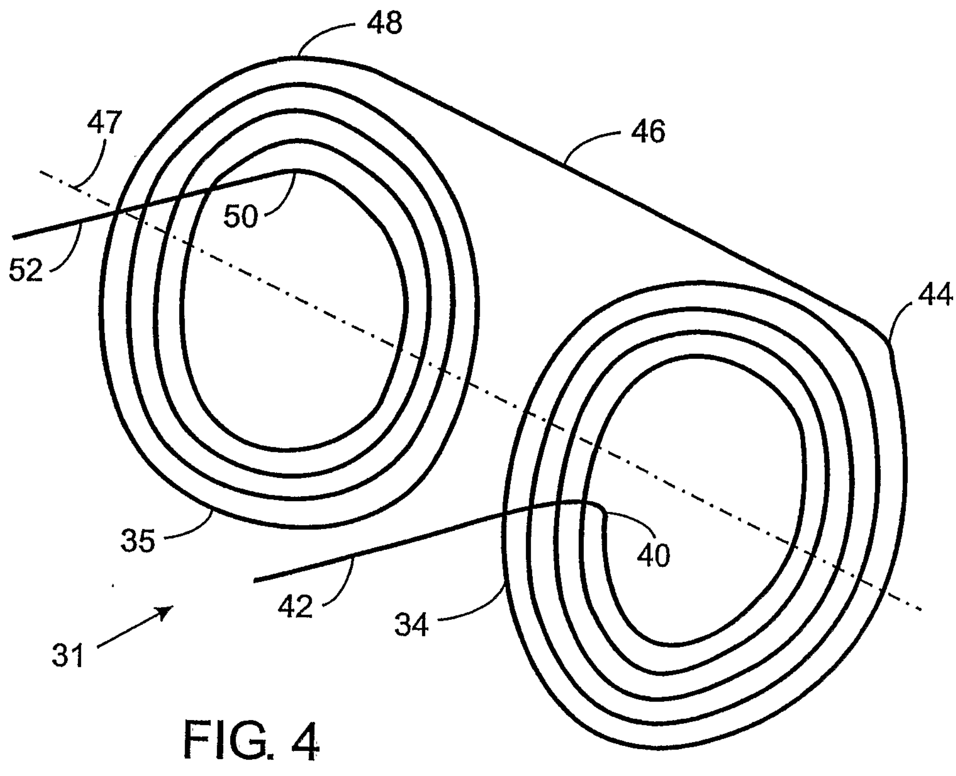
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FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/008020

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61N1/378 A61N1/362 H01Q7/00 H01Q21/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61N H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/171355 A1 (YU CHIH-HSIUNG ET AL) 2 September 2004 (2004-09-02) paragraph [0014] - paragraph [0018]; figures 2,3	1-5,8-10
X	US 6 009 350 A (RENKEN ET AL) 28 December 1999 (1999-12-28) column 12, line 27 - line 53; figures 10A,B	1-20
X	US 2004/088012 A1 (KROLL MARK W ET AL) 6 May 2004 (2004-05-06)	1-5, 8-10,15
Y	paragraph [0090]; figures 1,6	12-14
X	EP 0 989 384 A (BIOSENSE, INC; BIOSENSE WEBSTER, INC) 29 March 2000 (2000-03-29)	1-8
Y	paragraph [0002]; figures 1-3	12-14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
21 June 2006	30/06/2006

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/008020

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 058 330 A (BORZA ET AL) 2 May 2000 (2000-05-02) the whole document	1-20
A	US 6 445 953 B1 (BULKES CHERIK ET AL) 3 September 2002 (2002-09-03) cited in the application the whole document	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2006/008020

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